TRACE ELEMENT FRACTIONATION BY IMPACT-INDUCED VOLATILIZATION: SIMS STUDY OF LUNAR HASP GLASSES; J.J. Papike, M.N. Spilde, C. T. Adcock, G.W. Fowler, and C.K. Shearer, Institute of Meteoritics, Department of Earth & Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, U.S.A.

INTRODUCTION. Impact is the dominant process acting on the surfaces of atmosphere-free planets and asteroids once volcanic activity has ceased. It is the process that modifies both the physical and chemical character of surface planetary materials. Although the phenomenon of volatile element transport by impact was identified early in the study of the Apollo lunar samples, Naney et al. [1] systematically described and named an impact glass type with an unusually high Al and Si-poor nature and named it HASP. Since the Naney et al. [1] description of HASP glass, this glass type has been found in many Apollo lunar soils and breccias and in lunar meteorites (Warren and Kallemeyn) [2]. This paper reports our studies of HASP glasses with the ion microprobe. Our studies of lunar volcanic glasses demonstrated that we can measure Li, Be and B with great precision and accuracy (Shearer et al.) [3]. Brearley and Layne [4] measured Li, Be, and B in chondrules and considered their volatile behavior. They found that Be is positively correlated with Al showing that its behavior is strongly refractory and that Be is negatively correlated with the volatile LLE, B. We now want to see if these same systematics hold for HASP glasses which show a range of Al/Si ratios and have specifically targeted Apollo 14 impact glasses reported by Vaniman [5]. The experimental design is to determine the behavior of elements with a variety of volatilities with emphasis on the light lithophile elements (Li, Be, B), the REE (La, Ce, Nd, Sm, Eu, Dy, Er, Yb) and Sr, Y, Zr.

RESULTS AND DISCUSSION. We measured 11 HASP fragments from Apollo 14 regolith breccias 14076, 14160, and 14252. The HASP fragments from sample 14076 are distinctly higher in Al_2O_3 and were likely derived from anorthositic protolith [5]. The HASP fragments from samples 14160 and 14252 are lower in Al_2O_3 and have a KREEP signature. The protolith for these HASP glasses could have been Apollo 14 KREEPy soils and/or breccias. Some of the chemical attributes of these two HASP groups are shown in Figures 1 and 2. Figure 1 shows that Zr, Y, Be, and Li are in higher concentrations in the KREEPy HASP glasses then the anorthositic HASP glasses. Figure 2 shows the REE systematics. The KREEPy HASP glasses have elevated REE concentrations almost identical to the high-K KREEP of Warren [6]. The anorthositic HASP glasses have REE concentrations that are enriched relative to ferroan anorthosites (e.g. 15415) and with a flatter chrondrite normalized REE pattern slope. The major feature of these REE patterns is that the HASP fragments have enriched REE relative to their likely protoliths. This is probably mostly due to the significant loss of SiO_2 which is quite volatile relative to the refractory REE. The relatively flat slope of the REE pattern for anorthositic HASP relative to anorthosite could be due to two factors: 1) a small amount of KREEP in a dominantly anorthositic protolith and 2) more volatile loss of the LREE then the HREE (e.g. Boynton [7]). Because we believe we have a better estimate of the protolith composition for the KREEPy HASP than the anorthositic HASP we will focus our additional analysis on KREEPy HASP at this time. Figure 3 is a "spider diagram" comparing the average analysis of KREEPy HASP glass to its assumed protolith composition. Elements that plot at values >0.5 on this diagram are enriched relative to the protolith while those that plot below 0.5 are depleted. K_2O, Na_2O, SiO_2, and FeO are clearly depleted relative to the assumed protolith composition. These depletions are consistent with differential volatilization by Rayleigh fractionation [8]. Further interpretation of the elemental gains and losses are made possible by use of an "Isocon Diagram" (Figure 4) [9]. Figure 4 plots the concentration of elements in the KREEPy HASP glass versus its assumed protolith. Elements and oxides are appropriately scaled so all will plot on one diagram. If there were no elemental gains or losses, all points would plot along a 45° line. However, if there are elemental losses, as necessitated by a volatilization process, other systematics occur. The immobile or refractory elements will define an isocon whose slope gives an estimate of mass loss. In this case the isocon indicates a mass loss of 37%. Most of this loss can be accounted for by loss of SiO_2. Other elements that show significant depletions are K_2O, Na_2O, and FeO. Of the light lithophile elements Li, Be and B, B (although we do not have a good protolith estimate) and Li are depleted but Be behaves like a refractory element [4]. Also, although it is known that the REE have different volatilities [7], in this process of impact melting of lunar protolith they all behave in a relatively refractory manner.

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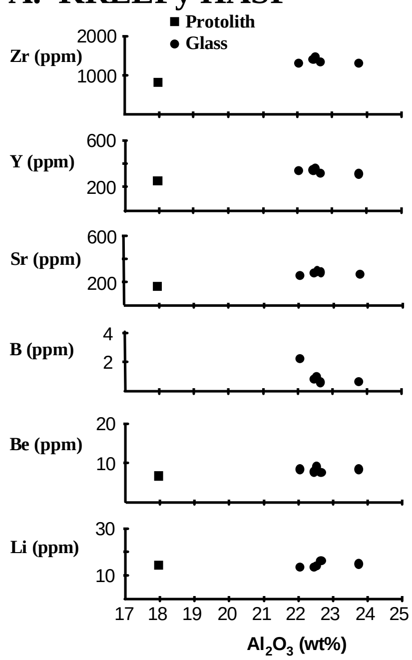
Figure 1

A. KREEPy HASP



B. Anorthositic HASP

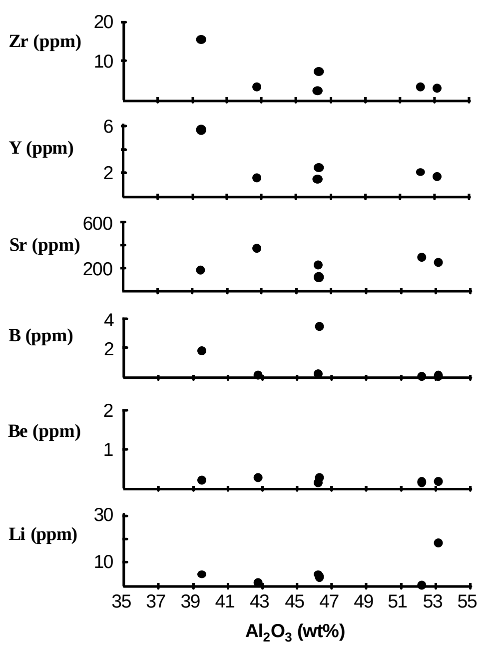


Figure 2

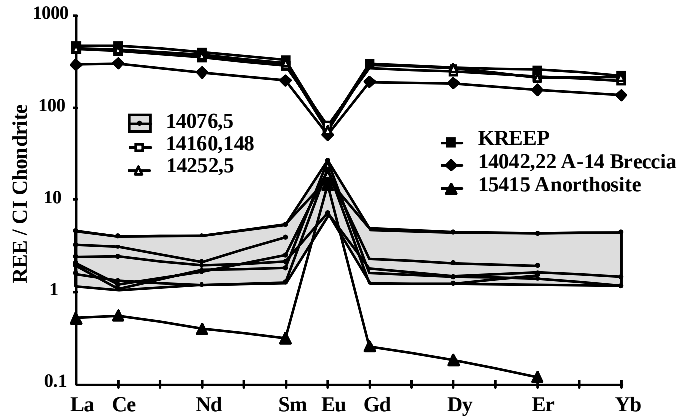


Figure 3

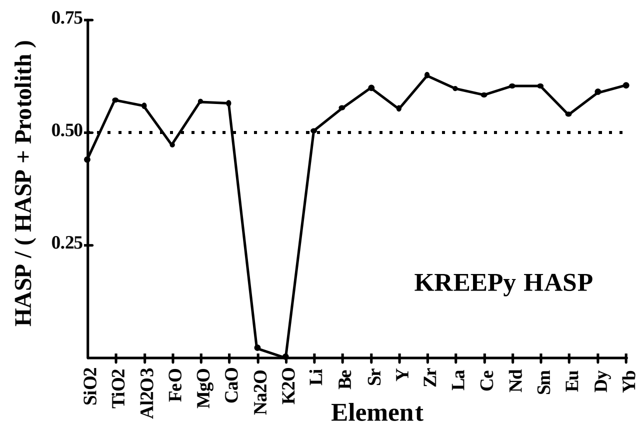


Figure 4